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A SURVEY OF RESEARCH DEMANDS IN IRON ORE

I.B. KLYMOWSKY AND J.M. WILSON

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by

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SUMMARY

From January 4th to 20th, 1979, the authors, I.B. Klymowsky and J.M. Wilson visited iron ore concentrating plants in Northern Ontario, Quebec, and Newfoundland for the purpose of identifying the current research demands of the industry and establishing a research program on iron ores in CANMET. During the sixteen-day tour the following operations were visited: Griffith Mine, Red Lake; Steep Rock Iron Mine, Atikokan; Sidbec-Normines Inc., Port Cartier; Wabush Mines, Pointe Noire; Iron Ore Company of Canada, Sept-Iles and Carol Lake; Mount Wright, Fermont; and Scully Mine, Wabush.

The companies all expressed interest in the fact that CANMET would again be doing research in iron ores, and indicated that this was a timely move. High labour and energy costs, combined with the decreasing grade of Canadian iron ores, have eroded much of the industry's competitive edge in world markets and have created a need to improve efficiency and recovery. For their part, the companies felt that they have been successful in overcoming many of their operating problems, but that the problems they now face require more time and expertise than they can afford to provide or maintain on their own.

There were many areas of common concern, which the companies thought could be organized into some sort of collective projects. Some of these are:

1) Control of ore variability with respect to beneficiation.
2) Providing more information on liberation characteristics.
3) Improving concentrate grade, lowering silica levels.
4) Improving recovery of fine iron.
5) Removal of alkalis.
6) Improving classification efficiency, particularly in hydrocycloning.
7) On-stream silica and particle size analysis.
8) Treatment of tailings water for recycle and disposal.
9) Reducing media consumption in regrinding in pelletizing.
10) Reducing filter-cake moisture.
11) Characterizing bentonite and improving mixing of bentonite in pelletizing.
12) Improving the screening of green pellets.
13) Reducing energy consumption in pellet induration.
14) Controlling pellet quality with respect to strength and size.
15) Providing material balances.

The background information from which the fifteen points listed above were extracted is given in the following sections on individual operations.

For the purpose of the Minerals Research Program these various elements could be organized into five projects:

1) Control of Ore Variability.

2) Process Development.

3) Pelletizing.

4) Water Treatment.

5) Circuit Monitoring and Analysis.

Griffith Mine

Pickands-Mather operate a concentrator and pelletizing plant at Red Lake, Ontario producing 1.5 million TPY of pellets assaying 66.8% Fe from a magnetite ore averaging 23.5% magnetic iron. There is a SL/RN direct reduction facility on the property which was shut down two years ago when the price of scrap iron fell below the price of reduced pellets. It is not anticipated to reopen in the near future.

The authors met with John Jeffries, General Manager; John Geddes, Assistant General Manager; Ben Eberts, Plant Superintendent; Tom Tonner, Assistant Plant Superintendent; and Hoe Teh, Metallurgist. Two discussion sessions were held, separated by a plant tour conducted by Tom Tonner. In the first session the company outlined their major problem areas, and in the second session, expanded on some of these:

i) Abnormally high fuel consumption in their shaft furnaces.

ii) Difficulties in the flocculation of tailings for disposal.

iii) Problems in characterizing and mixing of bentonite

iv) Coarse cobbing.

v) Cyclone classification.

vi) Flotation.

The shaft furnaces at Griffith use 750 thousand Btu/ton of pellets at a cost of $2 million per year, while smaller shaft furnaces at Erie Mining use only 500 thousand Btu/ton treating the same kind of material. Modern indurating machines, such as the Dravo travelling grates at Hibbing Taconite, use as little as 300 thousand Btu/ton. The problem at Griffith appears to be due to channelling and poor heat distribution. This may be caused by the size of the furnaces which are 30% larger than those at Erie. A request was made for a theoretical heat balance to determine the potential for energy reduction. This request was passed on to the Engineering and Economic Evaluation Section of CANMET and to the Chemical Engineering Section of NRC.

In regards to tailings, the problems are clarity of the thickener overflow water, and build-up of scale in the pipes. Lime is used in the thickener at a rate of 6 tons/day to raise the pH for flocculation to 10.8. The flocculant is an anionic polymer, Percol 156. The high lime additions have been found necessary for effective flocculation, however, they have also resulted in a severe build-up of scale in the pipes. On the basis that high pH promotes an increase in negative charge of particles and that the polymer itself is negatively charged, it was suggested that the calcium ion is responsible for flocculation and that calcium chloride may be used as an alternate source of calcium ion. Further research would be necessary to substantiate this claim.

Further discussions revealed that not all the tailings were difficult to flocculate. The problem appears to be most

severe with slimes in the primary tailings from autogenous grinding.

High-grade Wyoming bentonite is becoming increasingly expensive and difficult to obtain. Griffith use approximately 20 lb/ton bentonite imported from Federal Wyoming at a cost of $75/ton. Recently tests have been done using Canadian bentonite from Avonlea, Saskatchewan. The Canadian bentonite does not have the same sluffing characteristics nor the same affinity for moisture as the Wyoming bentonite, but is considerably cheaper, $55/ton. Some of the current problems in induration may be attributed to bentonite.

Mixing of bentonite with moist concentrate is another problem. The present Pekay mixers are dusty and inefficient. The company indicated interest in other mixers, particularly in a small ball mill used by the Japanese, and suggested that a technical evaluation be done of the various mixers available on the market. Canadian iron ore producers have a high regard for Swedish and Japanese technology and look towards the Federal Government as a source of first-hand information about this technology.

Coarse cobbing of run-of-mine ore was put forth as a project which would increase the company's ore reserves by permitting them to treat lower grade material. Cobbing is now done on some of the primary and secondary mill feed, and has been very successful in increasing mill capacity. A significant amount of gangue is rejected in cobbing, containing less than 2% Fe. Before implementing cobbing on run-of-mine ore, the company would like to know how large their iron losses would be.

Some interest was expressed in improving classification efficiency in cycloning. Six 20-in. cyclones are used to classify the primary magnetic concentrate and fourteen 10-in. cyclones are used to classify the secondary mill concentrate in each mill line. Large fluctuations in feed occur as a result of changes in ore hardness making it difficult to control underflow densities and cut-sizes. This is an area which has not been given much attention in the past, and our remarks with respect to characterizing the performance of hydrocyclones using model'ing concepts were welcomed.

The most significant iron losses occur in flotation. Magnetic iron recoveries are in the order of 95%; final recoveries are 85%. The flotation is done at a high pH with the primary amine, MG-70-A3. No iron depressant is used. There appeared to be a lot of fine iron floating in the roughers. Use of a depressant was suggested as a means of improving selectivity. Further research would be required to determine the best type of depressants and the cost-benefits of using a depressant.

The principal changes to the plant flowsheet as published in the CIM volume on Milling Practice in Canada[1] include:

1) Cobbing of the recirculating load to the autogenous mills, and of the pebbles to the pebble mills.
2) Installation of a scavenger magnetic separator after flotation, followed by .003" Rapifine screens and additional froth cleaner cells.

These changes have resulted in an overall increase in recovery of 1-3% at a grade of 69.5% Fe, and have fully paid

for themselves. Therefore small increases in recovery through further improvements in flotation would be of benefit to the company.

Steep Rock Iron Mines

Steep Rock Iron Mines are in the process of shutting down their mining and pelletizing operations. The authors visited the area because there are certain aspects of the operation which are of interest to the authors, and because this was an opportunity to learn more about Bending Lake which could give new life to the Steep Rock plant. At Steep Rock, the authors met with Larry Lamb, President; A. Boyles, Metallurgical Manager; and Pat Capper, Chief Metallurgist. Discussions were held on the possible uses of Steep Rock ore in the manufacture of brick and cement, on the problems with Bending Lake ore, and on certain aspects of the Steep Rock pelletizing operations.

Three factors have led to making the Steep Rock operation uneconomic:

1) Mining of the steeply dipping ore deposit at a depth of 1000 ft has resulted in a stripping ratio exceeding 5:1.

2) The iron content of the ore has been steadily decreasing.

3) The silica content of the pellets is too high to satisfy current demands of blast furnace operators.

The Steep Rock ore is an earthy hematite containing geothite, limonite, clays and pyrite. It grades from 40%-60% iron and 0-10% sulphur. Approximately 80% of the ore is direct feed for pelletizing while 20% is concentrator feed. The latter

is crushed to -3/4" and concentrated using jigs and spirals, yielding a recovery of 60-65% of the iron in a concentrate assaying 6.7-7.5% silica. Grade-control is practiced on the direct feed to pelletizing and on the feed to the concentrator[2].

In recent years, the company has been selling small quantities of pyritic crude ore (10,600 tons in 1977; 14, 150 tons in 1978) to Canada Cement and Inland Cement, however, they have not been able to secure a long term contract for this material. It would be possible to stockpile 100,000 tons of this material or reprocess the jig rejects if there were a long term contract.

Proposals have been made for manufacturing brick and tile from the clay found in the deposit. However, high freight costs and low value of the product mitigate against these proposals.

The sticky nature of the ore may make it useful as a binder in pelletizing. Steep Rock uses very little bentonite in pelletizing, approximately 14 lb/ton. Sometimes no bentonite is used at all.

An interesting feature of the plant is the grinding and pelletizing section. Grinding for pelletizing is done dry, in 12' x 16' peripheral discharge mills which were converted from rod mills to ball mills to obtain a finer grind and higher throughput. The dry-ground product is then mixed with Avonlea bentonite and fed to balling discs. Water is added directly to the discs. Sprays are not used. It was reported that Caland operate a similar grinding and pelletizing facility.

There is no screening of the balls before firing. Induration is done on a Dravo travelling grate equipped with 50 wind boxes. The energy consumption is 1.7 million Btu/ton of pellets; the capacity of the grate is 1.3 million TPY. Some of the windboxes are purged to remove arsenic and sulphur. Arsenic and sulphur are reduced from 0.03% As and 0.40% S in the feed to 0.014% As and 0.012% S in the pellets. Specifications on the pellets, which are all shipped to Algoma, are relatively low: iron-61%, silica-7.5%, sulphur-0.02%, compressive strength-400 lb, and tumble index-8% minus 28 mesh. However, the contract with Algoma gives no incentive to produce higher quality pellets.

In regards to Bending Lake, the principal problem is removal of the alkalis. At a meeting held in Duluth with representatives of the Algoma Steel Corporation, this problem was identified as one of the main stumbling blocks in the development of magnetite deposits in Northern Ontario.

The interest that Steep Rock has in Bending Lake is connected with the possibility of using the present plant to pelletize Bending Lake concentrate. The capacity of the grate, operating on magnetite, has been calculated to be 2.5 million TPY. The estimated cost of revamping the plant to handle the Bending Lake material is $20 million. Since Algoma has an interest in the Tilden Mine, it is doubtful whether this project will materialize in the near future.

The history of Steep Rock[3] and the huge water diversion project which accompanied the opening of the mine is a testament to the spirit and vision of Canadian mining men. It is estimated

that it will take 70 years to fill the pit with water. The closing of the mine will bring to an end one of the great achievements in Canadian mining.

Wabush Mines - Pointe Noire

Wabush Mines operate a 6.0 million ton per year pelletizing plant at Pointe Noire, Quebec, where concentrate brought by rail from the Scully Mine in Labrador is reground for pelletizing. After a tour of the plant conducted by Come Desmeules, discussions were held with André Demers, Resident Manager, Prakash Mullick, his technical assistant, George Rodgers, Chief Metallurgist, and Edgar Maes, Supervisor of Process Development. It was pointed out that the three major cost items in the plant were: Bunker C oil, bentonite and grinding media.

In an effort to reduce fuel consumption in induration, tests are being conducted with coke-breeze additions, following the lead established by Hoogovens in the Netherlands. The coke-breeze is being imported from Youngstown Steel and Contrecoeur, where it is used primarily for sintering. Theoretically, on a weight basis, 3.8% coke breeze should supply all the heat requirements for induration, however, in practice much smaller additions, in the order of 1.5%, have to be made to avoid sintering. With 1.5% coke breeze, it is anticipated that the heat requirements will be reduced from the present level of 985 thousand Btu/ton to 615 thousand Btu/ton. There are many other factors to consider with the use of coke breeze; among these are: the strength of the pellets, the effects of excess

heat on the grate bars, and effects on the temperature profile in the furnace.

Wyoming bentonite is used in pelletizing. It is imported from Wyoben at a cost of $50/ton. The quality of this bentonite does not appear to be as good as it was in the past, because much more is required (23 lb/ton as compared to 13 lb/ton 5 years ago). The bentonite is mixed with the concentrate from the dry grinding mills in a pug mill and water is added to provide a feed to the balling drums containing 7.8% moisture. One of the difficulties with the pug mills is that they produce too many seed pellets. (This problem might be overcome by installing a Pekay mixer at the discharge from the pug mills.) The balling drums are equipped with screens, but there are problems with blinding of the screens and with fines in the product. One balling drum is equipped with a vibrating screen, but still has the same problems. The most promising solution to this problem appears to be roller screens.

There are no scalping screens or "gooney" breakers for the oversize pellets which explode and create dust in the furnace. A program is being developed to monitor dust levels at the discharge of the furnace and relate these to the tumble index of the pellets. Tests are also being done to determine the optimum slope in balling to improve on-size recovery and minimize the production of oversize. The target in these tests is to produce pellets with 70% in the -1/2 + 3/8 in. size range.

Limestone additions have been made to improve the tumble index of the pellets (1% limestone provides a 1% improvement in the tumble index), but the cost of limestone has recently doubled. The company is looking for a local source of supply as an alternative to the limestone imported from Michigan.

The steel ball consumption in dry-grinding is 2.2 lb/ton, which is significantly lower than the 8-9 lb/ton steel ball consumption in wet-grinding at Sidbec Normines Inc., or the 5-6 lb/ton in wet-grinding at Carol Lake. Tests are being done to reduce costs even further by using slugs instead of 1 1/2" steel balls. The power consumption in dry-grinding is slightly higher than it was in wet-grinding, 28-30 kWh/ton as compared to 24 kWh/ton. The feed rate is controlled manually to maintain a grind of 62.5% minus 325 mesh. One of the problems in grinding is blinding of the grates, however, it has been found on occasion that mills with the worst blinding yielded the highest throughput. These observations may be explained by the fact that the grate area is too large for the grind that is required, and does not give the material enough residence time in the mill; as the grates become blinded, material is retained in the mill for a longer time.

A sampling problem was brought up in reference to the loading of pellets for shipment. A low-maintenance, automatic sampler for 4000 tons/hr that can function reliably in a dusty environment is required. An alternative solution to the dust problem, found in the course of our visits to IOC, is to spray the pellets with a starch solution.

In summary, the areas identified for research were:

1) Automatic grind control, including an on-stream particle size analyzer.
2) Reducing costs of the grinding media.
3) Better methods of mixing for pelletizing.
4) Improvement of green-ball properties, size and strength.
5) Use of coke-breeze in induration.
6) Correlation of furnace dust with tumble index.
7) Automatic sampling of pellets for shipment.

Scully Mine-Wabush

Pickands-Mather operate a concentrator at Wabush that processes 17 million TPY of ore grading 35% Fe to produce 5.8 million TPY of concentrate for their pelletizing plant at Pointe Noire. The authors met Nels Sherren, Assistant Resident Manager: Tim Eby, Concentrator Superintendent; Mike Iliffe and Denis MacGillivary, Metallurgists.

The ore is a friable specular hematite, containing small amounts of goethite, limonite, magnetite and pyrolusite (Mn). The primary concern at this time is to reduce the manganese levels in the concentrate to below 2%. It appears that in recent years the manganese content in scrap iron has risen to substantial levels, and blast furnace operators are demanding lower manganese in pellets. The manganese in the ore is concentrated in two size fractions: the plus 28 mesh, and minus 325 mesh fractions. These fractions are largely rejected in the concentrating process.

The ore is ground to minus 20 mesh in 24-ft-diameter autogenous mills. The feed rate to the mills is maintained at 400 TPH. The energy consumption is very low, approximately 2 kWh/ton, which probably explains why these mills are not controlled by power draft as is the usual practice in autogenous grinding. Preliminary beneficiation is done using spirals. The spiral concentrate is then dried and upgraded to 66.5% Fe, 2.5% SiO_2, and 2% Mn using electrostatic separation.

Several changes have been made in the circuit since publication of Milling Practice in Canada[1]. These include:

(1) A scavenger spiral circuit to treat the high-tension tailings.

(2) Two Jones high-intensity magnetic separators to treat the cyclone overflow fraction of the coarse spiral tailings.

The high-intensity magnetic separation circuit consists of: screening to remove trash oversize, low-intensity wet magnetic separation, desliming using cyclones to remove manganese slimes and two stages of high-intensity magnetic separation. It appears that the manganese is non-magnetic and can be rejected in the Jones machines. This circuit has provided an additional recovery of 300,000 TPY of iron concentrate, and the installation has fully paid for itself.

The problems identified in connection with the concentrator include:

1) Reducing manganese in the concentrate.

2) Improving liberation, and separation of middling particles in the form of "pepper quartz".

3) Improving classification in screening and cycloning.

4) Reducing moisture in the concentrate.

5) Improving recoveries in the WHIMS circuit.

6) Establishing a procedure for material balances in the concentration.

Sidbec-Normines Inc.

Sidbec-Normines operate a 6.0 million TPY (design capacity) pelletizing plant at Port Cartier which includes regrind mills and WHIMS to process concentrate from the Lac Jeannine concentrator into pellets. There are two product lines: blast furnace pellets 66.5% Fe, 5% SiO_2; and direct reduction pellets 68% Fe, 2% SiO_2. Initial production was begun in the fall of 1977 at an annual rate of 1.4 million TPY: production scheduled for 1979 is 4.6 million tons. A full description of the plant is given in Milling Practice in Canada[1] and in an article published in Skillings Mining Review[4]. Only some features of the plant are reviewed here. William Morimoto, Operations Superintendent, conducted the tour of the plant and was kind enough to stay late and provide the information for this report.

The concentrate is reground in six 17 1/2' x 34' open-circuit, wet ball-mills to between 64 and 65% minus 325 mesh (1500 - 1600 cm^2/gm Blaine). The mills use 1 1/2" balls and the ball consumption is very high, 8-9 lb/ton. This may be due to corrosion; the pH of the raw water is between 5.5 and 6.0. Dolomite is added to the thickener to raise the pH of the reclaim water to 8.0. The mills themselves are rubber-lined. Control

of grinding is maintained by means of the % solids and the feed rate. The feed rate is maintained at approximately 150 T/hr, and the % solids at approximately 74%. The total power draft on each mill is approximately 4500 kW, resulting in a power consumption of 30 kWh/ton. There are two advantages to grinding in open-circuit: one is that the size distribution of the product is wider than in closed-circuit grinding and more amenable to pelletizing; the other is that the heat generated in grinding greatly aids filtering. Temperature at the ball mill discharge is 150°C; at the filters is 120°F; and the filter-cake moisture is only 8.5%. IOC will be testing open-circuit grinding at Carol Lake.

The filter-cake is mixed with Wyoming bentonite, imported from Wyoben, in Littleford mixers. These mixers are quite efficient and no problem with seed pellets was identified. A comment was made that the company would like to use Greek bentonite, because it is cheaper and just as good as the present Wyoming bentonite. Bentonite consumption is in the order of 20 lb/ton. There was a problem at one time with hang-ups in the filter-cake bins, however, this problem has been overcome by lining the bottoms of the bins with plastic liners.

Balling is done in open-circuit on 25' Dravo-type discs. It was stated that discs have a higher production capacity than drums, require much less maintenance, and provide a cleaner operation. There was no spillage around the discs. The feed rate to the discs is approximately 185 tons/hr, and the product size is 83% -5/8 + 3/8 in. Screening of the pellets is done by means of roller conveyors at the head of each of the

travelling grate furnaces. The company has redesigned the roller conveyers to accomodate a second deck for removal of oversize pellets. The oversize pellets, are shredded in a double-roll shredders designed and manufactured at the plant. An excellent machine shop allows the company to make many innovative improvements in their plant.

Upgrading of the concentrate to 68% Fe, 2% SiO_2 is done using six Jones high intensity wet magnetic separators; each has a design capacity of 80 tons/hr. The feed system to the upgrading plant is unique, employing a loop-belt conveyor. Scalping screens remove plus 28 mesh material to prevent blocking of the Jones plates; this material assays 67.9% Fe and is blended with the magnetic concentrate. Weight recovery on the WHIMS is 83%, and the iron recovery is 96.5%. The tailings assay 28-29% Fe, and research is being done to recover a few more iron units from these tailings. The magnetic concentrate is dewatered using cyclones and fed to the regrind mills. Difficulties are sometimes encountered in providing a steady feed to the mills when operating the upgrading circuit.

The two travelling grate furnaces each have a design capacity of 3.0 million TPY. Energy consumption is presently at 900 thousand Btu per ton. Significant reductions in energy consumption are anticipated through improvements in screening, and with the use of coke-breeze. Some problems were encountered with swelling of the pellets, and 1% additions of dolomite from Michigan are presently being made to overcome this problem. A more recent problem is the formation of cracks in the pellets.

In summary, the Sidbec-Normines plant is perhaps the most impressive pelletizing facility in Canada, featuring many innovations in operation and design. Some of the problems identified at this time are:

1) High ball wear 8-9 lbs/ton in grinding.
2) Pellet swelling and cracking.
3) Maintaining steady feed to the regrind mills from the upgrading plant.

Lac Jeannine

Quebec Cartier Mining operate the Lac Jeannine concentrator at Gagnon for Sidbec-Normines Inc. The authors met with Pierre Dagneau, General Superintendent; Jacques Diotte, Division Superintendent; Paul Gagnon, Concentrator Superintendent and Sami Nosseir, Manager of Process Development. The ore, a specular hematite, is shipped by rail from the mine at Fire Lake, some 55 miles away. It is crushed to 8" and ground in twelve 18 x 5 ft. wet autogenous mills. The grinding circuit is closed with 3-mm screens, and the circulating load is approximately 30%. Concentration is done using spirals. Recoveries from high grade ore (36-39% Fe) were reported to be 85%.

At present only 40% of the plant water is reclaimed from the thickener. It is anticipated that greater use will be made of reclaim water from the Lac Jeannine pit as the operation progresses.

There are two types of ore at Fire Lake, hard ore and soft ore, and the grade varies from 29% Fe to 40% Fe. Although such variations are detrimental to the operation of the

concentrator, no grade control is practiced at the present time.

The problems that have occupied the staff of the concentrator are:

1) Increasing the liberation of the hematite.

2) Increasing mill throughput.

3) Treatment of the red tailings water.

The ore from Fire Lake is somewhat finer-grained than the ore from Lac Jeannine. Trials will be run with 2-mm screens to improve liberation.

In order to produce 6.0 million tons of concentrate, it will be necessary to maintain a throughout rate of 140 TPH per mill. The throughput rate with some of the hard ore has been as low as 120 TPH. Tests have been done using steel ball additions, and increases in throughput as high as 165 TPH have been achieved. However, a better alternative would be to blend 20% hard ore with 80% soft ore. This would necessitate a program of controlling ore variability at the mine.

Another method of increasing production would be to improve recovery of fine iron. The alternatives being considered at the present time include Reichert Cones and WHIMS. Flotation has been rejected on environmental grounds.

Treatment of the red tailings water was identified as a urgent problem at Lac Jeannine. A process is being worked out by Dearborn Chemicals for Mt. Wright. It will probably be applied to the Lac Jeannine tailings. At present the tailings are pumped into the abandoned Lac Jeannine pit.

Mount Wright

At Mount Wright, the Quebec Cartier Mining Company operate an 18 million TPY concentrator. The authors met Ghislain Bourque, Assistant to the Director of Research and Engineering, and C.E. Head, Chief of the Research Laboratory.

The Mt. Wright ore is a specular hematite, averaging 34% Fe, and containing less than 5% magnetite. There is considerable variation in ore grade and grindability,in spite of the fact that the ore is blended from many different locations in the mine. The ore is ground to minus 20 mesh in six 32' x 12' autogenous mills, each in closed-circuit with two 6-mm scalping screens and eighteen 2-mm finishing screens. The circulating loads are in the order of 25%. The feed rate to the mills is controlled by the power draft, and averages 1050 TPH.

Concentration is done using Elliot double-helix spirals. The feed to the spirals is dewatered using cyclones, and the cyclone overflow is discharged to three 250-ft thickeners. The tailings are split into two products, a coarse tailing and fine tailing, by means of a specially designed splitter box which removes fines from both the inside and outside portions of the spiral stream. The fine tailings are also dewatered using cyclones, and the cyclone overflow is discharged to the thickeners. Calgon 502 (cationic polyacrylamide) is used to facilitate thickening. The pH is 7.4.

A WHIMS machine has been installed at the thickener underflow to recover the fine iron. However, grades no higher than 60% iron have been achieved.

The most impressive feature of the plant is "Arnold", the Foxboro process control computer which was installed to facilitate the plant start-up. It is now used to control feed rates, monitor bearing temperatures, schedule maintenance, and automatically control shut-downs and start-ups.

The problems identified for research were:

1) Fine iron recovery.
2) On-stream iron and silica analysis.
3) Treatment of the red tailings water.
4) Reduction of filter-cake moisture.

For fine iron-recovery the company is considering Reichert cones and WHIMS. Flotation has been rejected on environmental grounds.

No instrument has been found, with sufficient sensitivity, for analyzing the coarse material which the company processes.

A $1 million treatment plant has been installed by Dearborn Chemicals to treat reclaim water from the thickener overflow. However, the tailings pond effluent is still not being treated.

Steam hoods have been installed on the filters to reduce filter-cake moisture to 4%.

Interest was also expressed in models for computer control of grinding and beneficiation.

Carol Lake

The Iron Ore Company of Canada operate a 22-million TPY concentrator and pelletizing plant at Carol Lake. The authors met with Colin Jardine, General Manager; Rod Coles, Concentrator Superintendent; Steve Vessey, Pellet Plant

Superintendent; Sam Elgohary, Supervisor of Process Engineering; and An Mai, Supervising Metallurgist.

Mr. Jardine outlined a Pellet Plant Research Program aimed at reducing: fuel consumption in induration, steel ball consumption in grinding, filter-cake moisture, as well as improving pellet quality. The program included:

1) Testing of open-circuit grinding for pelletizing.
2) Testing different grinding media-high Cr-alloy steel balls.
3) Studying application of a particle-size analyzer.
4) Steam heating of slurry to aid filtering.
5) Control of bentonite additions
6) Conversion to roller conveyers for screening the green pellets.
7) Designing a new, more efficient burner for the grate furnace.
8) Coke-breeze additions.
9) Studying the induration temperature profile.
10) Monitoring dust levels.

Fuel consumption in induration is approximately 5 gallons of oil, or 900,000 Btu/ton. One advantage at Carol Lake is that the ore contains 14% magnetite.

The tumble index of the pellets is 94, and Q index is 91; improvements could be made through better screening of the green pellets.

Some consideration has been given to the use of gas in induration. Gas would reduce costs of maintenance and

reduce production losses due to down time, because the furnaces would require relining every 5 years instead of every year as is the current practice.

A description of the concentrator and some of the operating problems was given in a report issued by Klymowsky and Sirois in 1977[5]. Improvements have been made in concentrate grade and mill throughout through the monitoring of silica levels and through modifications to the primary autogenous mills.

Mill throughput has been increased 15% by the removal of the deflector rings in the Aerofall mills, and by the change-over from peripheral discharge to trunion discharge.

Silica levels in the concentrate are maintained at 4.5%. Any further reduction in silica levels would require significant modifications to the present circuit. Investigations are being carried out at the Hanna Research Laboratories in Hibbing, Minnesota to upgrade Reichert cone concentrate from coarse spiral tailings using flotation.

Research is also being done on controlling ore variability. Traditionally the weight yield at 66% iron determined the cut-off grade. The minimum acceptable weight yield is 34%. A formula has been developed to include other factors for detemining the cut-off grade: magnetite content, limonite content, grindability index and liberation.

Sept-Iles Concentrator

At Sept-Iles, the Iron Ore Company of Canada operate a 6.0 million TPY concentrator and pelletizing plant to treat Schefferville ore. The authors met R. Geren, Executive

Vice-President; R. Stahlberg, Technical Assistant to Mr. Geren; B. Gagnon, concentrator Superintendent, and attended a special meeting with the staff of Schefferville and Sept-Iles to discuss the research needed to improve flotation at Sept-Isles. The principal subject of the meeting was the report written by I.B. Klymowsky on the Flotation Behaviour of Schefferville ores[6]. The basic problems identified were:

(1) Variability of the Schefferville ores.

(2) Flotation of coarse silica.

(3) Retention time in flotation.

The research proposed to overcome these problems includes:

1) Mineralogical investigations of feed, concentrate and tailings to identify factors which affect grinding and flotation.

2) Testing of different reagents for the flotation of coarse silica.

3) Material balances to determine retention time.

4) Desliming to improve selectivity in flotation.

Other problems identified with respect to the concentrator include:

(1) Improving classification in cycloning.

(2) Reducing the amount of plus 100-mesh material in the feed to flotation.

(3) Froth handling.

(4) Elimination of froth on the thickeners.

(5) Tailings water treatment to remove suspended solids.

(6) Improving filtration of the thickener underflow.

The pelletizing plant uses 1.3 million Btu/ton of pellets for induration. Research is being done with coke-breeze additions to lower energy consumption, and with better methods of screening to improve pellet quality. The bentonite used in pelletizing is the same as at Carol Lake, Greek bentonite. Some of the problems in pelletizing include mixing of the bentonite and controlling of the moisture of the concentrate.

The induration is done in an Allis-Chalmers grate kiln. One of the principal problems are hot-spots on the kiln shell which cause frequent shut-downs for relining. A study has been made of the possibilities of using gas instead of oil for firing the kiln to rectify this problem.

The most recent development at Sept-Iles is spraying of the pellets with a starch solution to reduce dust in loading and transportation.

CONCLUSIONS

Problems in Quebec, Newfoundland and Ontario differ in as much as the regions treat different types of iron ores: Ontario primarily treats magnetite ores, while Quebec and Newfoundland primarity treat specular hematites. Ontario operators use natural gas in firing their pellets, while Quebec operators use Bunker C oil. Iron recoveries from magnetites are

higher and Btu consumption is lower. Therefore the emphasis on specific research areas is different in the different regions. In Ontario the emphasis is on increasing concentrate grade and on alkali removal, whereas in Quebec and Newfoundland the emphasis is on fine iron recovery and reducing Btu consumption. One area which is becoming increasing important in all regions is the treatment of tailings water.

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